(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organizati n
International Bureau

(43) International Publication Date
26 April 2001 (26.04.2001)

PCT

(10) International Publication Number
WO 01/29527 A1

(51) International Patent Classification[7]: G01K 11/00

(21) International Application Number: PCT/IT00/00426

(22) International Filing Date: 23 October 2000 (23.10.2000)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
CZ99A000010 22 October 1999 (22.10.1999) IT

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(81) Designated States (*national*): AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW.

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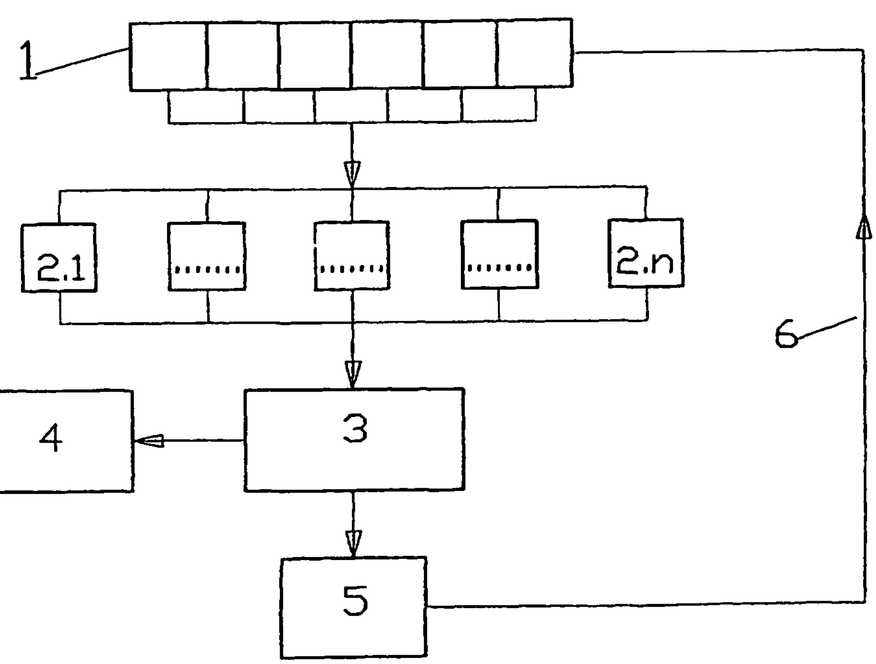
(54) Title: METHODS AND EQUIPMENT FOR THE MEASUREMENT OF THE THREE-DIMENSIONAL DISTRIBUTION OF THE TEMPERATURES WITHIN DIELECTRIC MEANS



(57) Abstract: The present invention concerns methods and instruments for the definition of the three-dimensional distribution of the temperature of dielectric objects, non-invasively. It is based on the possibility of measuring with extreme precision the electromagnetic heat emission that results within the internal presence of objects with temperatures superior to absolute zero.

WO 01/29527 A1

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHODS AND EQUIPMENT FOR THE MEASUREMENT OF THE THREE-DIMENSIONAL DISTRIBUTION OF THE TEMPERATURES WITHIN DIELECTRIC MEANS

A new type of tomograph has been invented that is able to rebuild the three-dimensional distribution of the temperatures present within the dielectric objects, including biological objects. Although the instruments may be used in all fields, one of its most important uses is that which in the medical-diagnostic field, considering that it may allow the definition of the three-dimensional thermal map of human internal organs.

The instrument is made up of:

1. Electromagnetic wave emission sensors that are able to detect radiation with wave lengths that go from the millimetre, centimetre, and metre waves to those of the infrared radiation.
2. All structural elements and the mechanical and electronic accessories necessary to assemble and move the aforesaid sensors, so as that the sensors themselves can detect most suitably the heat emissions of the dielectric objects, according to the given directions and distances.
3. An electronic co-ordinator for the automatic management of the instruments.
4. Software for machine management and for the elaboration of the three-dimensional distributions of the temperatures in the dielectric objects.

DESCRIPTION OF THE PREVIOUS STATE OF THE ART

The present invention concerns an instrument and a methodology for the determination of the three-dimensional distribution of the temperatures of the dielectric objects, non invasively. . It is based on the possibility of measuring with extreme precision the electromagnetic heat emission that results within the internal presence of objects with temperatures superior to absolute zero. All bodies that are furnished with such temperature distributions irradiate electromagnetic radiation in accordance with the law of Plank: from a physical point of view there is thus a certain quantity of internal heat that is irradiated externally as electromagnetic radiation. The power emitted depends principally on the temperature of the body and on the emission properties of the same body. The electromagnetic wave emission power of the objects can be described as not very elevated frequencies (until the infrared zone) through Raley Jeans type equations and it proves hence to be directly proportional to:

- the square frequency
- the emission coefficient, between zero and one, that in turn depends on the frequency,
- the body temperature,
- the Boltzman constant.

The emission power however, at room temperature, reaches the maximum in the infrared zone, but decreases, exactly squarely as compared to the frequency, for lower frequencies. because of this, the detection of the power irradiated by the object in millimetre, centimetre and metre waves, becomes a much more critical problem and requires extremely sensible sensors. Surveys that are able to precisely measure the objects' emission power, in this frequency range, have become accessible in the last years. The first surveys, in this frequency field were the Dicke radiometres (1;2). However even these

sensors have not been greatly used because of the measurement errors introduced principally by the reflection of the irradiating power emitted by the objects on the level of the interface between the same objects and the surveyor's antenna. There have been various attempts to correct this undesired effect. An initial solution to the problem was presented by Ludeke et. Al. In 1978 (3). While more recently, more effective solutions were presented by Troitskii and Raklin (4), and Holodilov and Ulianichev (5). The latest generation of sensors, commonly defined as radiothermometers now allows to measure with extreme precision the physical temperature of the dielectric objects without errors caused by the reflection of the power that irradiates towards the interface between the object and the sensor antenna. In the radiothermometer proposed by these authors, the antenna is connected through a modulator of the first arm of a circulator. The second arm of this circulator is connected to the input of the radiometer. The radiometer has within itself a reference high tension generator that feeds the modulator. In this case a resistance, in thermal contact with the temperature transducer, is the noise generator. The output of the resistance is connected both to the output of the radiometer, through a high frequency de-coupling element (inducer), and to the third arm of the circulator through a fitting condenser. The radiometer stops feeding the resistance when its temperature is identical to the object's.

Ultimately the problem of detecting electromagnetic emission in the wave length field that goes from millimetres to meters can be considered solved and the present invention, that will use as electromagnetic radiation sensors the aforementioned radiometers, benefits from this.

The instrument object of the present invention requires the extension of the frequencies detectable until the infrared zone. This proves comprehensible if one considers that the penetration power of the electromagnetic waves in the dielectric objec ts is directly proportional to the wave lengths of the radiation, which in turn inversely depends on the square root of the dielectric constant of the intersected object. When it is required rebuild the internal temperature distribution of a determinate object it is therefore necessary to have at one's disposal detectors that are sensible to an ample range of frequencies so as that measuring the power irradiated in growing wave lengths, starting from infrared, deeper and deeper layers of the investigated object are gradually characterised. The necessity of extending the frequency field to the infrared is not a problem because the availability of the infrared sensors is much broader (6)

Even if the instrument, object of the present invention, is useable in all fields in which one wishes to determine the three-dimensional distribution of the temperatures within any dielectric object, a particular important application regards the building of three-dimensional thermal maps in human internal organs and from this point of view the instrument is of great interest for medical diagnostics. In order to illustrate the effect on the medical diagnostic sphere and the considerable innovation level, its use will be referred to as Radiomammograph that is as an apparatus that is able to produce three-dimensional thermal maps of internal sections of the breast. This internal organ is particularly exposed to tumour pathology attacks. Breast cancer is one of the main problems of modern oncology. At the moment the most used diagnostic method for a breast tumour is the X - ray mammography of which

have been seriously analysed both the use limitations and the diagnostic criteria. It is a universally recognised fact by this time that x-ray application in mammographs currently in use represents an important factor of tumour pathology induction. In 1997 the World Health Organisation has identified the Mammography as the third risk factor for breast cancer. Hence many important world health organisations such as the Department of Health Service (USA) and the National Cancer Institute (USA) urge the scientific world to develop new methods for the precocious diagnosis of breast cancer. For some years now the possibility of applying to the diagnosis of breast tumour techniques such as MRI (Magnetic Resonance Imaging) and PET (Positron Emission Tomography) has been experimented, that however the analysed organs to strong electromagnetic field whose effects on the cells are not completely known. Besides these methodologies, because of their expensiveness and the various limitations that they encounter, cannot be used for population prevention screening.

The mammography technique, in addition to the inconvenience represented by its intrinsic invasiveness and riskiness, presents still another important limiting factor: its low spatial resolution on soft tissues. In the case of breast cancer its is ver y difficult to diagnose tumours whose size are inferior to two centimetres. that generally have behind them already have a long incubation period.

The present invention reproposes amongst other things the solution of the problem of precocious detection of breast cancer through the application of an investigation method that is able to discover the presence of a tumour in its initial development phase. In particular the present invention regards a method and its relative instruments for the building of three-dimensional thermal maps that allow the identification of inflammation centres o tumour masses or whatever else with its presence within tissues is able to modify it even weakly (tenth of degrees). Explicitly referring to the identification of tumour pathologies it is detected that the tumour tissue differs from the healthy one for a series of biochemical parameters. The tumour cells present a low accumulation efficiency of the metabolic energy that is dispersed thermally, giving rise to a temperature increase of the tumour mass as that of the healthy tissues. It is furthermore acknowledged that any local inflammation cause is however linked to more or less localised temperature increases.

INVENTION PRESENTATION

The methodology that is proposed concerns the non invasive definition of the three-dimensional distribution of the temperatures within the dielectric objects, with the inclusion of biologic tissues and organs. This methodology will use sensors that are able to measure the heat radiating power emitted by the objects at different frequencies, within the range that goes from the radio waves (wave length one metre)to infrared (wave length one micron). The reception apparatus of such sensors will be directed in space according to fitting directions that will depend on the geometry and dielectric characteristics of the analysed object. Given that the effective layer thickness that contributes to radioactive emission depends on the wave length of the monitored radiation, it will be possible to rebuild the three-dimensional distribution of the temperatures, within the analysed volume, that is the value of the corresponding temperatures at small values (pixels) within the total analysed volume, measuring the power irradiated at different frequencies and placing the sensor antenna in

correspondence of a chosen set of points on the surface that circumscribes the investigated volume. Beginning from the thermal data measured at various frequencies and from various surface points, the rebuilding of the three-dimensional thermal maps of the investigated objects will be obtained through the application of opportune algorithms that will naturally take into consideration the topological data of the problem. The best approach for the solution of the problem of the rebuilding of the thermal field according to point values, initiating from integral data of the irradiated power, is based on the use of the Raley-Jeans equation, that describes the connection between the emission spectral density and the kinetic temperature of the elements of the object. On the other hand the reconstruction algorithms of the three-dimensional thermal distribution may be based on models in which the link between the emission intensities and the temperature profiles are expressed through first order Fridgolm integrals (7, 8).

The instruments, proposed in the present invention, will allow the measurement of the total emissions of electromagnetic field at various wave lengths, in the range between infrared and radio waves, and throughvarious observation directions.

It will therefore contain a series of sensors that are able to measure the electromagnetic field in specific spectral bands. Such sensors are mounted on supports that adjustable and removable in space, so as that, remaining fixed the object of which one wants which to determine the three-dimensional distribution of the temperature, the various sensors can be positioned in such a way as to measure the emission along directions that have been pre-established by the observer. The movement of the sensors may occur both automatically and manually.

The data measured by the sensors are sent through opportune interfaces to the data memorisation system that are able to re-elaborate the experimental information (total emission of electromagnetic waves of the object at various wave lengths and through various directions and/or distances), resolving integral equations with Fridgolm type methods, setting as output the three-dimensional map of the temperatures of the object. Such a map in addition to being supplied as a table can be presented on a screen or also printed as a thermal image.

An incomplete structural outline of the proposed instrument is reported in figure 1

The sensor battery (1) may be oriented on the basis of a program that the operator can elaborate during the analysis. For example, the operator, on the basis of the observations, at certain wavelengths representative of the surface thermal distribution, can determine topological parameters for the sensor movement operating at gradually growing wavelengths to better define the heat determinations of the deeper layers of the object. The output of the different frequency channels 2.1 ……. 2n will be charged in command centre 3, that contains in its interior the elaboration and co-ordination unit of the entire instrument.

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CLAIMS

1. Instrument for non invasive measurement of the three-dimensional distribution of the temperatures of dielectric objects, with the inclusion of human organs or other biological tissues, characterised by the fact that it uses sensors to determine the electromagnetic heat emission power in a frequency range between the radio wave frequency and the one of infrared radiation, mounted on supports that are adjustable and movable in space, so as that, remaining fixed the object of which one wants to determine the three-dimensional distribution of the temperature, the various sensors can be positioned in such a way as to measure the emission along directions that have been pre-established by the observer. The movement of the sensors may occur both automatically and manually. The data measured by the sensors are sent through opportune interfaces to the data memorisation system that are able to re-elaborate the experimental information (total emission of electromagnetic waves of the object at various wave lengths and through various directions and/or distances), resolving integral equations with Fridgolm type methods, setting as output the three-dimensional map of the temperatures.

2. Instruments for non invasive measurement of the three-dimensional distribution of the temperatures of the dielectric objects according to the second claim characterised by the fact that the maps are supplied as a table.

3. Instruments for non invasive measurement of the three-dimensional distribution of the dielectric objects according to the second claim characterised by the fact that the maps are supplied on a screen.

4. Instruments for non invasive measurement of the three-dimensional distribution of the temperatures of the dielectric objects according to the second claim characterised by the fact that the maps are supplied as thermal maps

5. Non invasive measurement methods of the three-dimensional distribution of the temperatures of the dielectric objects using an instrument of the type described in any of the claims from 1 to 4 according to the second claim characterised by the fact that it uses a reconstructive approach of the point like temperatures based on the use of the Raley-Jeans or similar equations, that uses calculus algorithms of the three-dimensional thermal distribution may be based on models in which the link between the emission intensities and the temperature profiles are expressed through Fridgolm integrals equations or by other similar equations.

6. Non invasive measurement methods of the three-dimensional distribution of the temperatures of the dielectric objects according to claim n° 5 characterised by the fact that the registration of the

thermometric data, the data registration and its handling, both automatically through opportune algorithms, apart from their specific nature.

7. Non invasive measurement methods of the three-dimensional distribution of the dielectric objects according to claim n° 5 characterised by the fact that it is used for medical-diagnostic purposes, on human internal organs.

8. Non invasive measurement methods of the three-dimensional distribution of the temperatures of the dielectric objects according to claim n° 5 characterised by the fact that the operator manually determines topological parameters for sensor handling working on gradually increasing or decreasing wave lengths.

9. Non invasive measurement methods of the three-dimensional distribution of the temperatures of the dielectric objects according to claim n° 5 characterised by the fact that the sensor handling is automatic and occurs according to pre-established programs, that can be chosen by the operator.

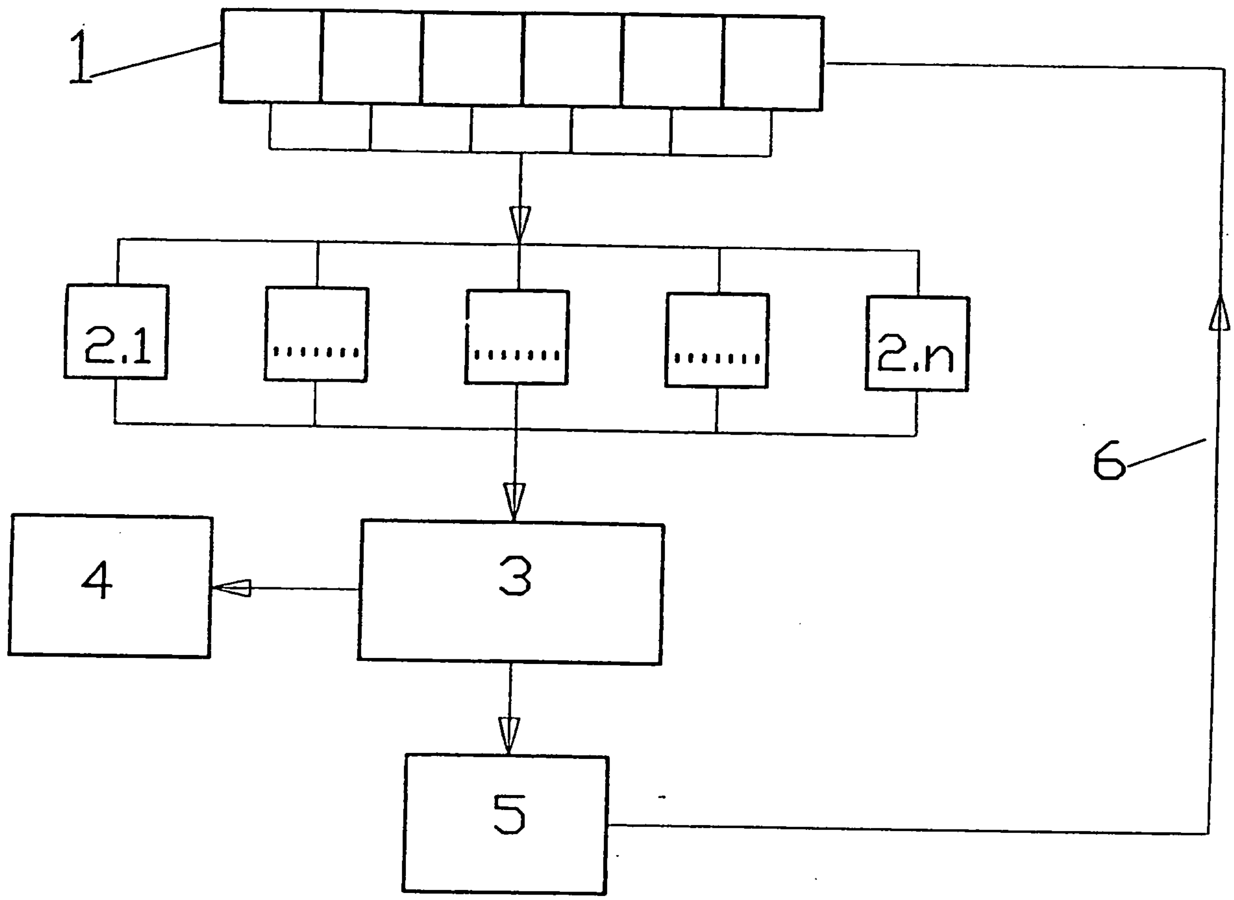

fig. 1

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